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ABSTRACT

This first in a series of seven modules for a course titled Nondestructive Examination (NDE) Techniques I describes visual examination as an independent inspection activity. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, and (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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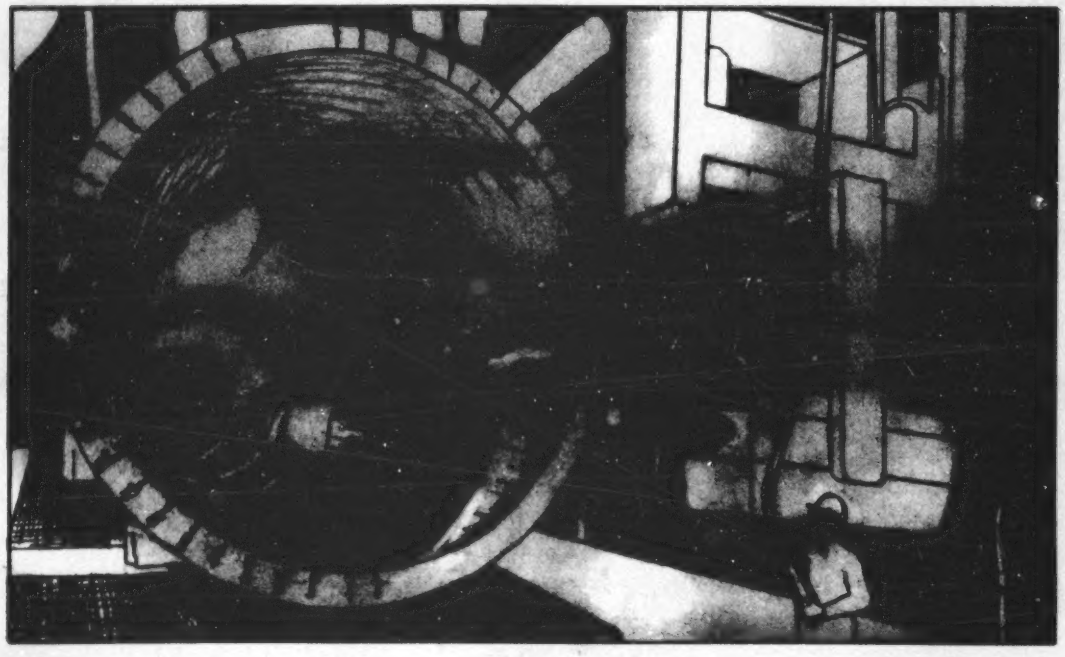
NUCLEAR TECHNOLOGY

COURSE 26 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I

MODULE 26-1 Visual Tests



CE 024 240

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 26 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I

Module 26-1 Visual Tests
Module 26-2 Leak Tests
Module 26-3 Hydrostatic Tests
Module 26-4 Liquid Penetrant Tests
Module 26-5 Fundamentals of Radiography
Module 26-6 Radiography Inspection
Module 26-7 Radiographic Specifications and Code Requirements

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This module was prepared for General Physics Corporation by Ed Wasil, General Physics Corporation.

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1979

INTRODUCTION

Visual examinations are widely used throughout industry. They comprise some of the most important of all product examinations. Many product characteristics are accepted based solely on visual examination and most other types of examinations employ visual examination to some extent.

Contrary to first appearance, visual examination is not particularly simple. When visual examining an item, what does one see? What should one look for? How does lighting level and type of lighting affect the results? What is acceptable or unacceptable? These are but a few questions which can be relevant to proper performance of visual examination.

This module describes visual examination as an independent inspection activity. It describes features of those examinations performed altogether visually. The concepts presented will also apply, at least in part, to the visual examination portions of all other types of examinations which employ visual techniques.

Initial Activity

Prior to studying this module, the student/trainee is encouraged to perform the activity described below to gain an initial appreciation of visual examination.

This activity requires that you examine your hand which is not used for writing. Complete the activity by accomplishing each of the following instructions in the order they are presented.

- Visually examine, for 4 or 5 seconds, your hand that is not used for writing.
- Place the examined hand out of view, such as under your desk or table, and do not look at it again until instructed to do so.

- Very candidly, complete the following statements and answer the corresponding questions.

  (1) May hand is normal abnormal
  What are the abnormalities, if any?

  (2) My hand has four fingers and one thumb. true false.
  Where these actually counted? yes no.

  (3) All of the four fingernails are present not present.
  Where these actually counted ? yes no.

  (4) How many of the fingernails are split? _____.
  Was this characteristic looked for? yes no.

  (5) The hand is clean not clean.
  Was cleanliness actually looked for? yes no?

  (6) There are _____ (number) of rings on the fingers of the hand.
  Was the number of rings actually counted? yes no?

  (7) Each finger, if complete, has three phalanxes.
  Which fingers have hair in the area of the middle phalanx.
  index finger
  middle finger
  ring
  little finger
  none
  Was this characteristic actually looked for?
  yes no?

- Count the number of yes and no answers and calculate your inspection efficiency.

  ____ yes answers
  ____ no answers

$$\text{efficiency \%} = \frac{\text{number of yes answers}}{\text{total number of yes and no answers}} \times 100\%$$

- Reexamine your hand and check your entry for normality of the hand. Look for scars; unhealed cuts, burns and abrasions; warts; moles; missing nails, digits or other portions; and split nails. If any of these are present, your hand could be considered abnormal. Was your initial answer correct?
- Reexamine your hand for cleanliness. Is there any evidence of dirt, ink, pencil marks, or stains? Are the nails clean? Was your initial answer correct?

MODULE PREREQUISITES

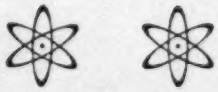
None.

OBJECTIVES

Upon completion of this module, the student/trainee shall be able to do the following:

1. Define visually discernable attribute and name at least seven characteristics of product which are visually discernable.
2. Given any of ten characteristics which are visually discernable, describe the make-up of the characteristics as applied to visual examination.

3. Name six techniques for performing visual examination and describe each.
4. Name two types of physical acceptance standards and differentiate the use of each.
5. Give two reasons why physical acceptance standards are beneficial to visual examination.
6. Name three personnel skills and physical qualities and relate them with their effect on visual examination.
7. State four advantages and disadvantages of visual examination.
8. Name three types of operations where visual examination is typically employed by any company and give the purpose of each application.
9. State the application of translucent visual examination and briefly describe how this examination is performed.



NOTES TO INSTRUCTOR / STUDENT

It is recommended that activities be established for student/trainee visual examination of product. Guidelines for such activities are given by the module.

Advance preparation will be necessary to obtain product and associated drawings or written acceptance standards. Such products could be scrap components obtained from nearby industries. Products produced by work shops within your institute may be obtainable. Also, relatively inexpensive products could be purchased e.g., fasteners, fittings, spacers, washers, etc. Details of the visual examination exercises will be discussed later in this module.

SUBJECT MATTER

ELEMENTS OF VISUAL EXAMINATION

What comprises visual examination? What are its basic elements? While there are many factors involved to varying degrees dependent on specific applications, the elements of any visual examinations involve the questions of what, how, why and by whom. What can be visually examined? How should visual examination be performed? Why is it performed? By whom should it be performed? Answers to these questions are expressed within four basic elements of visual examination:

- visually discernable attributes
- visual examination techniques
- acceptance standards
- personnel skills and physical qualities.

Visually Discernable Attributes

Visually discernable attributes are product characteristics capable of being examined visually for purposes of comparison to a standard. A product characteristic is visually discernable if it can be seen and judged to a standard either quantitatively or qualitatively. Therefore, the acceptance standard determines whether a given product characteristic is visually discernable. For example, sorting pipe lengths by 4, 6, 8, 10 and 12 feet increments can be accomplished visually, but judging if a given pipe is within its 1/16 inch tolerance for length cannot be done solely by visual examination.

Product characteristics which are visually discernable typically fall into ten categories. These are identity, certification, count, shape, orientation, contour, surface condition, cleanliness and preservation.

- identity - This characteristic refers to both the kind of item and the identification marking on the

item. First, is the item the kind of item required? For example, if the item is supposed to be a 300 gallon per minute centrifugal pump, is it? The visual examiner sees that it is a pump, its shape is of the centrifugal design, and its nameplate identifies its capacity as 300 gallons per minute. Secondly, is the item properly identified? Using the same example pump, the visual examiner determines from the drawing or specification that a nameplate is required which identifies name, classification, flow capacity, pressure rating, and serial number. Visual examination of the nameplate data determines compliance with these requirements. There are many case histories of problems with identification marking. Most pertain to legibility and omissions. There are also case histories of problems with incorrect kind of items. Examples include 3 position switches where 4 position switches were required, fasteners with course threads were required, incorrect size of fittings, and incorrect grade of materials.

- certification - This characteristic refers to certification paperwork from one company to another and to completion of paperwork within a company. In the first meaning, certifications are provided for delivered items in the form of Certified Material Test Reports for materials and Data Reports for components. The visual examination always includes checking for presence of these documents and may include review of their content. In some cases, the visual examiner refers the documents to engineers or specialists for review of content. The second meaning of certification pertains to checking for signoffs of prior operations at the time of visual examination. The visual examiner determines that paperwork accompanying the product has been signed for prior operations.

- count - The physical count of an item is frequently important. The count may be associated with a whole unit or with individual features of the unit. Case histories abound on problems which could have been avoided by proper count. Four terminal relays have been received when five terminals are required. Work has been drastically delayed when the supposed number on hand was found to be a lesser number. Examples of count are:
  (1) number of units received or issued.
  (2) number of bolt holes.
  (3) number of nozzles.
  (4) number of support mounts.
  (5) number of terminal boxes.
  (6) number of terminals within a box or on a relay.
  (7) number of strands within a wire or cable.

- shape - This characterisitc refers to the overall space envelope occupied by an item. It is the outline of the item from a number of viewpoints. Again, case histories abound on problems with shape. Examples include incorrect or omission of weld joint preparations and square head bolts vice hex head bolts.
- orientation - Experienced inspectors have a saying, "Does it look like the drawing?" They are mentally picturing the shape and orientation elements and comparing them with the drawing. Orientation refers to agreement between the product's physical configuration and that required by the drawing. One of the most difficult orientation problems to detect is the "mirror image" where the item is 180° out of orientation. At first appearance, it "looks like the drawing" but closer examination reveals that left-hand features

are on the right side and vice versa. Recently, a reactor pressure vessel was installed only to discover that all nozzles were 180° misoriented. While function was unaffected, major rerouting of piping was necessary at a large cost. Examples of features particularly susceptible to misorientation are:

(1) bridge wall arrows which indicate direction of flow
(2) nozzles
(3) bored and drilled holes
(4) support mounts
(5) terminal boxes
(6) vents and drains
(7) test connections

- contour - This characteristic refers to the shape of the surface of a feature whereas the characteristic of shape refers to the overall shape of the item. As applied to visual examination, it calls for a qualitative judgement on surface elements such as flatness, roundness, straightness, waviness and profile. Probable the most common application involves profile, i.e., does the surface outline look like the drawing? It is this application which quickly distinguishes a dromedary from a bactrian camel. A specific feature almost always examined solely by visual examination is the "breaking of corners". Designs frequently require a bevel or radius relief on inside and outside corners to reduce the stress concentration in service. The presence of such relief is determined by visual examination.
- surface condition - This characteristic refers to surface roughness and flaws. Roughness is defined as space surface irregularities. Flaws include cracks, pits, gas blow holes, nicks, scratches, gouges, seams,

and burrs. There are many case histories of items received with unacceptable surface conditions.

- color - Oftentimes, color is not relevant to visual examination of nuclear products. When it is, it typically pertains to the desired color or a product rather than the ability to distinguish a defect by its color. For example, electrical wire and cable are visually examined for insulation or covering of proper color. Raw materials are frequently identified by marking with a color-code scheme. On the other hand, a material flaw may be accompanied by a discoloration. Normally, visual examination is concerned with the presence of the flaw and not associated color characteristics.
- cleanliness - This characteristic refers to an absence of foreign materials on inside and outside surfaces of an item. Visual examination for cleanliness normally involves looking for dirt, lint, oil, grease, scale, loose oxides, and any other object which should not be present. Again, case histories of insufficient cleanliness abound. The most dramatic ones involve objects such as pieces of grinding wheels or cleaning cloths found in components upon system flush after the components have been installed.
- preservation - As used here, preservation includes any special treatment of a surface which preserves the surface in storage or in use. With this definition, it includes plating, hard surfacing, coating, and painting. Visual examination determines the presence of preservation and the surface condition and cleanliness of the preservation surface. It also includes presence and count of dessicants which are sometimes required for items in transit or storage. Desiccants control humidity by moisture absorption.

Visual Examination Techniques

The best technique for performing visual examination varies somewhat from one application to another. Visual examinations of individual parts may look for only one or two characteristics while examination of assembled components or installed systems may look for all visually discernable attributes. Nonetheless, there are six techniques common to all visual examinations. These techniques are described as follows:

- establish the attributes to be examined - Prior to commencing visual examination of product, the specific product attributes to be examined are determined. Preplanned inspection check lists may list these or the inspector may be expected to determine such attributes from the drawing or written standard governing the product. Exercising this technique firmly establishes what attributes are viewed and tends to avoid omission of attributes by the examiner.
- establish a routine sequence of examination - Once the attributes to be examined are known, a pattern for their examination helps to ensure that each is examined. The exact sequence used is a matter of personal preference. However, use of the same sequence each time provides for fastest examination and least probability of omission of examinations. Using a routine sequence is particularly important for examination of assemblies and installations where many or all visually discernable attributes are examined. In such cases, the author recommends the following sequence:
  (1) identity
  (2) certification
  (3) count

(4) shape
(5) orientation
(6) cleanliness
(7) contour
(8) surface condition
(9) preservation

- ensure proper lighting - Light directed onto the product, reflected light from the product, and background light all affect ability to perform visual examination. However, the "proper" lighting is open to diverse opinions. For accurate conclusions on lighting effects, work-place studies using real product are the best solution. Nonetheless, the following generalities typically apply.
  (1) intensity of 50 to 150 foot candles is normally sufficient.
  (2) direct lighting tends to cause more eye fatigue than indirect lighting.
  (3) light reflected from the surface of the product causes eye fatigue and, dependent on the surface, can mask the characteristics looked for. Placing direct lighting sources slightly behind the examiner will tend to cause reflected light to bounce away from the examiner and reduce fatigue.
  (4) insufficient background light causes eye fatigue; however, extraneous light can interfere with the examination.
  (5) certain types of light "enhance" the product characteristic. For example, the ghoulish green light of mercury units tend to give a three dimensional appearance to flaws on highly polished surfaces.

(6) the type of light influences the color appearance of the product.

- use of aids as necessary - Visual aids refer to any device which increases capability of performing visual inspection. Aid typically include portable light sources, mirrors, magnifying lenses, physical acceptance standards, and measuring devices. These are described as follows:

(1) portable lights - These include flashlights as well as portable fluorescent or incandescent lamps connected to electrical power outlets. The latter are preferred because their intensity is more stable.

(2) mirrors - A wide variety of mirrors, handles, extentions, flexible joints, and holders are available. Whenever the eye cannot be placed within 12 to 20 inches of the surface, mirrors should be used. Also, mirrors should be used if the surface cannot be viewed from 60° either side of perpendicular to the surface. Self illuminated mirrors, such as borescopes, are used for examining inside surfaces of tubing and other inaccessable areas.

(3) magnifying lenses - Mangification is used primarily to examine "suspect" conditions, i.e., those characteristics which appear to border on the acceptance standard limit. However, acceptance standards sometimes require a specific magnification, e.g., no cracks when viewed at 5X.

(4) physical acceptance standards - Product specimens are sometimes used as a physical acceptance standard. When they are used, the examiner must use the same techniques for viewing the

acceptance standard as used for viewing the product. This means using the same lighting, mirrors, and magnification, as applicable.

(5) measuring devices - Visual examination is frequently used for examining size or form features whose dimensions need not be accurately measured. In such cases, devices are employed to aid in the visual measurement. Such devices include templates, overlays, fixed contour gages, fixed radius gages, straight edges, and fixed length standards. Placing the device against the product feature permits visual comparison for acceptance purposes.

- look for the oddity - Once the examiner has become thoroughly familiar with exactly what is acceptable, time and energies are wasted if the examiner ponders on conditions equal to or better than the acceptance standard. The story is told of a pioneer trapper who came to the clearing with his cabin and surveyed the area. The story tells of all the detail present in twigs, leaves, tree trunks, grass, stones, flowers, moss, and so on. Yet, the story states the trapper didn't see a thing! But, had there been one detail which had been disturbed, the trapper would have detected it instantly, for his life depended on such vigilance. The visual examiner must acquire the habit of instantly seeing the oddity, the unusual, or that which is not as it should be.
- examine for all required attributes - The visual examination is incomplete until all required discernable attributes are examined. When defects are found, a tendency exists to report those defects and terminate the examination. Inspection must guard against premature termination of the examina-

tion. Correction of reported defects is normally verified by reexamination of the correction only. Any attributes not examined initially remain unexamined.

Acceptance Standards

Acceptance standards for visual examination are stated by drawings or specifications or both. When drawings are prepared to include all acceptance standards required by governing specifications, only the drawing is used to plan for and perform visual examination. However, when the drawing references governing specifications for acceptance standards, both documents are used. When both documents are used, the QA/QC department normally prepares visual examination instructions which delineate the acceptance standards of the specification. In this manner, the visual examiner can perform the examination using the drawing and the prepared instructions without researching a specification to extract those requirements pertinent to visual examination.

The acceptance standards given by the product drawing and specification dictate the attributes to be examined. For example, if acceptance standards are given for surface flaws but not for surface roughness, the examination looks for flaws only. The QA/QC department of many companies prepare inspection instructions which delineate the specific attributes to be examined by the visual examiner. Other companies require the visual examiner to determine from the drawing (and possibly the specification) those attributes to be examined. The former practice has a primary advantage over the latter practice in that consistency among examiners is better ensured by ruling out individual interpretations.

In lieu of providing written acceptance standards, physical acceptance standards are frequently employed for visual examination. There are basically two types of physical standards: limit standard and range standards.

The limit standard represents the minimum acceptable condition of the product. Therefore, any product that appears to be worse than the standard is unacceptable.

The range standard is comprized of a range of appearances from clearly acceptable to clearly defective. From this standard, all concerned parties (engineering, quality control, customer representatives) agree on either the exact single limit standard or several limit standards which establish "grades" of defects.

Physical acceptance standards provide for more accurate visual examinations for two reasons:

- more concise meaning is conveyed to the visual examiner than by written standards.
- direct comparison of the product with the acceptance standard is provided.

Personnel Skills and Physical Qualities

Mostly, visual examinations employ the senses and mental intelligence. Manual dexterity is not particularly important. The qualities which are demanded of the visual examiner are visual acuity and color discrimination, knowledge of product processing, and conscientiousness. Each of these qualities are described as follows:

- visual acuity and color discrimination - Near distance vision is important to all visual examinations. Candidates for visual examiners are required to pass a near distance visual acuity test such as demonstrating the ability to read Jaeger #1 letters at a distance of 12 to 18 inches. The examiner is repeated annually since visual acuity can change with time. If corrective lenses are required to pass this test at any time, corrective lenses must be used whenever performing visual examinations. Color

discrimination is normally not required for visual examination. When color is an attribute being examined, the candidate must pass a color discrimination test. This test is not repeated because color perception does not change with time.

- knowledge of product processing - Visual examiners are better equipped to detect defects if they understand causes of possible defects. Knowledge of prior processing and the characteristic defects of such processing helps the visual examiner to know what is being looked for. Similarly, knowledge of subsequent processing and the effect of defects on such processing helps to establish the importance of the acceptance standards. For example, seeing a burr prohibit later assembly gives a better appreciation for the limits on the burrs.
- conscientiousness - Repetitive visual examination of items creates monotony. Visual examination of assemblies and installations may be tiresome because many surfaces and attributes must be viewed. Everyone has probably heard versions of the three eyewitnesses to an automobile accident who upon testifying appeared to be describing three different accidents. The visual examiner must know what to look for and diligently look. The examination must be as critical of the last piece as the first. Each attribute must be examined no matter how many exist. Therefore, the visual examiner must be conscientious. Such conscientiousness must recognize when fatigue or distractions are interferring and act to eliminate them. With respect to eye fatigue, short rest break are normally sufficient. The eye has great recuperative ability and a few minutes rest normally restores the necessary alertness.

APPLICATION

Advantages and Disadvantages of Visual Examination

Visual examinations are employed for determining acceptance of any attribute that is visually discernable in terms of the acceptance standard. This is because of the overwhelming advantages of visual inspection as compared to other examination methods. These advantages are as follows:

- Typically faster and cheaper
- Employs little or no test equipment
- Typically requires little environmental controls
- Adaptable to any job site location
- Capable of examining many different attributes within a single operation.

As previously emphasized, visual examination is limited to applications where compliance with acceptance standards is visually discernable. Therefore, the limitation of sight is the largest disadvantage of visual examination. When visual examination is employed, its other disadvantages are compensated for by training of personnel, using visual aids, and, if necessary, reexamining product by a second examiner. The other disadvantages are as follows.

- Susceptible to variance in results due to human factors
- Susceptible to variance in results due to lighting
- Difficulty of measuring size and form

Application to Product Life Cycles

Visual examinations are employed at each place of the product's life cycle as illustrated in Figure 26-1-1.

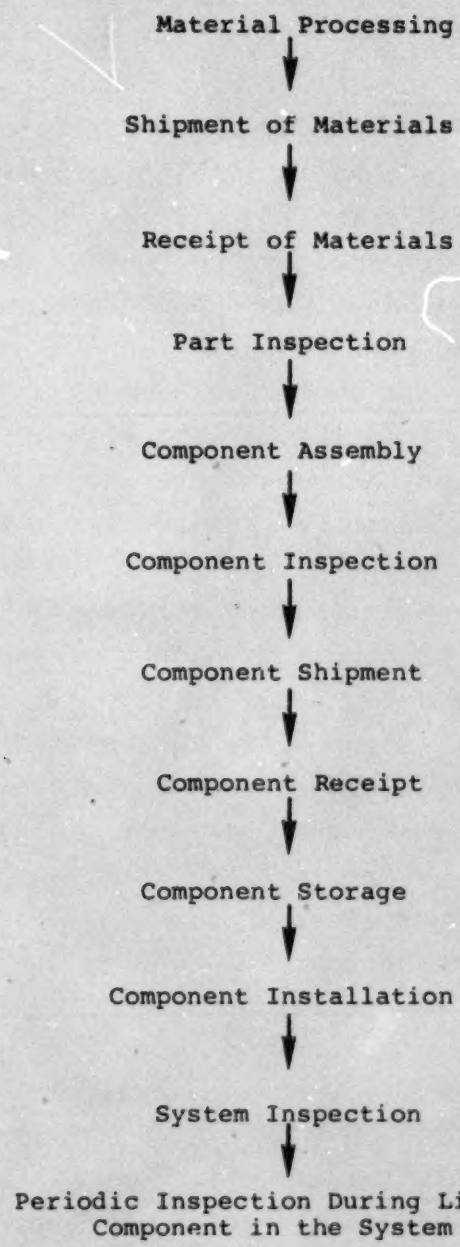


Figure 26-1-1 Application of Visual Examination to Product Life Cycle

Within a given company, the product life cycle illustrated in Figure 26-6-1 typically occurs within three types of operations.

Visual examination is normally applied to these three operations. These operations and the purposes of visual examination for each are:

- receipt of items - Visual examination determines that the items received are those ordered and are acceptable.
- final part of component inspection - Visual examination determines that visually discernable attributes of the part or component in its final state are acceptable. This examination is normally performed immediately prior to release for shipment.
- assembly or installation - Visual examination is typically applied at the outset of assembly or installation and either periodically or continuously throughout the assembly or installation. It confirms use of correct items, use of work practices which do not degrade the quality of the items, and acceptability of the completed assembly or installation.

Translucent Visual Examination

A special application of visual examination is termed translucent visual examination. This type of examination employs the properties of directional lighting to examine translucent materials. Collimated light is directed through the material such that the light is evenly diffused through the material. Flaws in the material or variances in material thickness are visible as areas of different light density when viewed from the side opposite the light source. The intensity of the collimated light source determines the sensitivity of the examination. Background lighting must

be less than the applied light on the surface being viewed and must be arranged to eliminate surface glares and reflection.

EXERCISES

It is recommended that products be obtained for visual examination by students/trainees. The products could be scrap components obtained from nearby industries or relatively inexpensive purchased components such as fittings, threaded fasteners, spacers, washers, etc. Either drawings or written acceptance standards should be available for each type of product. Guidelines for two activities in connection with each type or product are given below.

Exercise #1, Preparation of Visual Examination Procedure

1. Given: A product and its corresponding drawing and/or written acceptance standard.

2. Task: Prepare a procedure which gives instructions for visually examining the product. Include the following in the procedure as appropriate:
   a. attributes to be examined
   b. visual aids to be used
   c. lighting to be used
   d. sequence of examination
   e. record to be completed

Exercise #2, Performing Visual Examination

1. Given: A product, its corresponding drawing or written acceptance standard, and visual examination procedure.

2. Task: Perform the visual inspection in accordance with the procedure. Prepare a report which describes the following:
   a. each defective product noted and reason for considering it defective
   b. adequacy of procedure; for each inadequacy, state specific improvement recommended.

MATERIALS

1. Product suitable for visual examination
2. Drawings and written acceptance standards for such product
3. Portable lighting
4. Assortment of mirrors, magnifying lenses, rules, radius gages, fixed length standards and templates as required for the visual inspection.

PROCEDURES

In performing the exercises suggested for this module a written procedure for a visual examination is requested. Ensure that the written procedure identifies:

1. What can be visually examined?
2. How should visual examination be performed?

3. Why is it performed?
4. By whom should it be performed?

DATA TABLE

None.

REFERENCE MATERIALS

J.M. Juran, Quality Control Handbook, McGraw-Hill
Kennedy and Andrews, Inspection and Gaging, Industrial Press
American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section V, ASME, New York, N.Y.

TEST

1. Briefly explain what is meant by each of the following product characteristics which are visibly discernable:
   a. identity
   b. certification
   c. shape
   d. contour
   e. surface condition.

2. Briefly explain the importance of proper lighting in performing a visual examination of a product.

3. List five visual aids which may be used to increase the capability of performing a visual inspection.

4. Acceptance standards for visual examination are stated by drawings or specifications or both. Explain two types of physical acceptance standards and differentiate the use of each.

5. Briefly explain three personnel skills and physical qualities and relate them to their effect on visual examination.

6. List three advantages and three disadvantages of the visual examination.

7. Explain the purpose of the translucent visual examination.